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Appendix K
LRB External
Acoustic Power
Levels

Liquid Rocket Booster (LRB) for the Space Transportation System (STS) Systems Study

(NASA-CR-183797) LIQUID ROCKET BOOSTER (LRB) FOR THE SPACE TRANSPORTATION SYSTEM (STS) SYSTEMS STUDY. APPENDIX K: LRB EXTERNAL ACOUSTIC POWER LEVELS (Martin Marietta Corp.) 7 p

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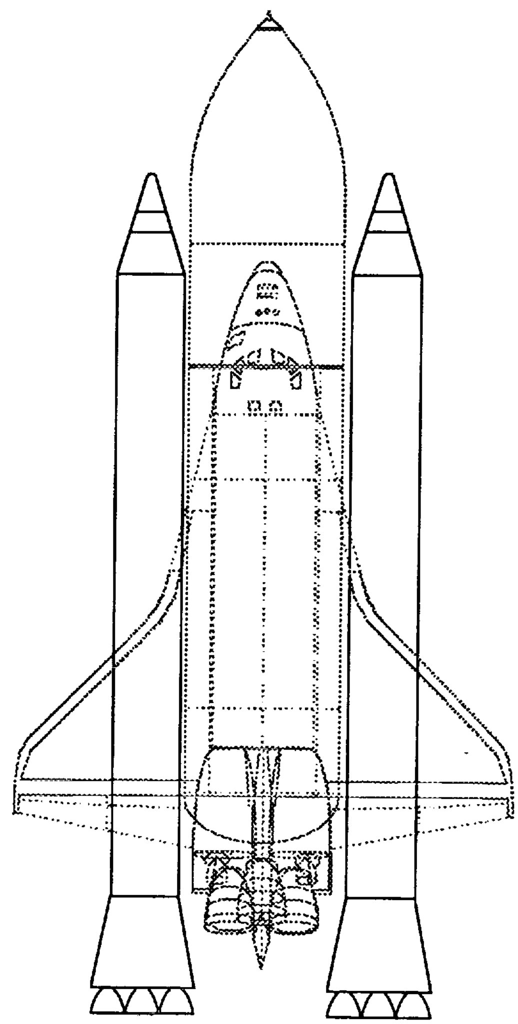

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LRB External AcousticPower Levels

Appendix K

LRB ASCENT EXTERNAL ACOUSTICS

SUMMARY :

- SRB's are main acoustic sources for the Shuttle.

- LRB's emit the same acoustical energy as SRB's (within 1dB). However the spectra shift by 0.84 to 1.49 depending on nozzle exit conditions selected.

- There are two nozzle exit conditions possible : a) 1-D plume characteristics at nozzle exit plane, based on Lewis CEC code; b) isentropic expansion (or contraction) of 1-D flow to sea level pressure. It is recommmended that 1-D sea level condition be used. Spectra ratios for this condition are 1.49 for the pump fed, and 1.20 for the pressure fed i.e. LRB spectra will be slightly higher frequency than SRBs.

- Near SSME's (i.e. at Orbiter aft bulkhead) use measured data from STS 1,2,3 without any changes.

- At other locations on the Orbiter take measured spectra and shift them by appropriate amounts.

- Data presented in report is to be used as external sound pressure level (SPL) for the calculation of interior acoustic field.

- Greatest difference from SRB data in any 1/3 octave band is 4.5 dB for a frequency shift of 0.84 (at Orbiter bottom panels, aft). This implies an acoustic power increase of 2.8 in that bandwidth. This is a concern but not a showstopper.

LRB ASCENT EXTERNAL ACOUSTICS

MAIN ARGUMENTS

- There is no LRB acoustic test data availble.

- LRB' acoustics estimated from : a) flight test data, b) model test data, and c) LRB acoustic power estimates and scaling laws.

- Flight data was measured during STS 1,2,3.

- Model test data measured for SSME's only, SRB's only, and both together. Tests reported in ref 4 were at MSFC 6.4% Acoustic Model Test Facility (AMTF) for the ACC studies. Earlier tests (reported in refs. 5,6) were without ACC. For these tests frequency scaling is the inverse of the spatial scaling. Results of model tests are plotted in fig.3. Model test data correlates well with test data as shown in figs 4-7.

- Figs 4-7 show that SPL from SRB only is very similar to that from SRB and SSME together. SRB level is approx 10dB higher than SSME only. Hence we can ignore the effect of SSMEs, except in their very near vicinity.

- Therefore at Orbiter aft bulkhead use measured data unchanged.

- For all other areas SRB is the dominant noise source. A method is developed for obtaining the external acoustic field due to the LRBs.

- Early LRB assessments (refs 7,8) were made for 1-D Plume characteristics and plume power levels obtained for two nozzle exit conditions : a) conditions at nozzle exit plane, and b) isentropic expansion (or contraction) of flow to sea level pressure. Using a ratio of 0.5% for conversion of mechanical energy to acoustic LRB plume acoustic powers can be obtained.

- Plume acoustic power levels of both Pump Fed and Pressure Fed LRBs is within 1 dB of SRBs.

- Scaling relationships between SRBs and LRBs indicate that LRB spectra do not differ by much as shown on p4 of the report.

- Hence LRBs will dominate the acoustics for all points on the Orbiter which were dominated by SRBs.

- It is recommended in ref. 8 that 1-D sea level results be used. Spectrum ratios for this are 1.49 for Pump Fed LRB, and 1.20 for Pressure Fed.

LRB ASCENT EXTERNAL ACOUSTICS

OBSERVATIONS :

Main observations listed on p5 are :

- Flight test data indicates that external acoustic spectra at the aft bulkhead of the orbiter is primarily due to SSMEs.

- Model data indicates that SRB is the main acoustic source for all other locations.

- Acoustic scaling laws indicate that LRBs will dominate the acoustic spectra at all points that were dominated by SRBs.

A method for predicting LRB spectra is developed based on above observations. This method is given on p5 under sample calculations.

LRB ASCENT EXTERNAL ACOUSTICS

COMMENTS ON METHOD OF SPECTRA CALCULATION :

- Measured STS 1-3 acoustic data given in Appendix B in 1/3 octave bands.

- This 1/3 octave data converted to a narrow band (1Hz) equivalent spectrum.

- Narrow band spectrum is frequency shifted by the frequency ratio obtained from scaling laws (0.84, 0.98, 1.20, or 1.49).

- Calculated narrow band data can then be converted to new 1/3 octave band levels. A set of results, for a frequency shift of 1.0, is included to verify the technique.

- Results for frequency ratios (0.84, 0.98, 1.0, 1.20, 1.49) is tabulated in App B in 1/3 octave bands.

- Results for narrow band (1Hz) calculations are plotted for scaling ratios of 0.84, 1.0, 1.20, 1.49 in figs 9-12.

- Do not modify aft bulkhead data.

- Greatest difference from SRBs in any 1/3 octave band is 4.5 dB (position 3, ratio 0.84) due to shift in spectra. This requires a 2.818 increase in power level in that bandwidth.

- Data is to be used as external SPL needed for calculation of interior acoustic field.

LRB ASCENT EXTERNAL ACOUSTICS

OTHER CONSIDERATIONS :

- Acoustic maxima occur between 60 and 120 feet above the pad as the vehicle lifts off - about 5 secs after SRB ignition.

- Method of calculation gives the maximum level that can be expected.

- It is possible, if unlikely, that shock cell oscillation in the plume may add another 6-10 dB to noise levels. Experience with jet aircraft indicates that such oscillations can easily be suppressed by altering the symmetry of flow.

- An effect that was not considered was the influence of 4 separate nozzles on the radiated sound field. Out-of-town expert opinion is that this effect is unimportant.

- LRB overpressure effect is expected to be less than SRB.